

VEHICLE SHUT DOWN

APPROACH HIGH-VOLTAGE VEHICLES WITH EXTREME CAUTION!

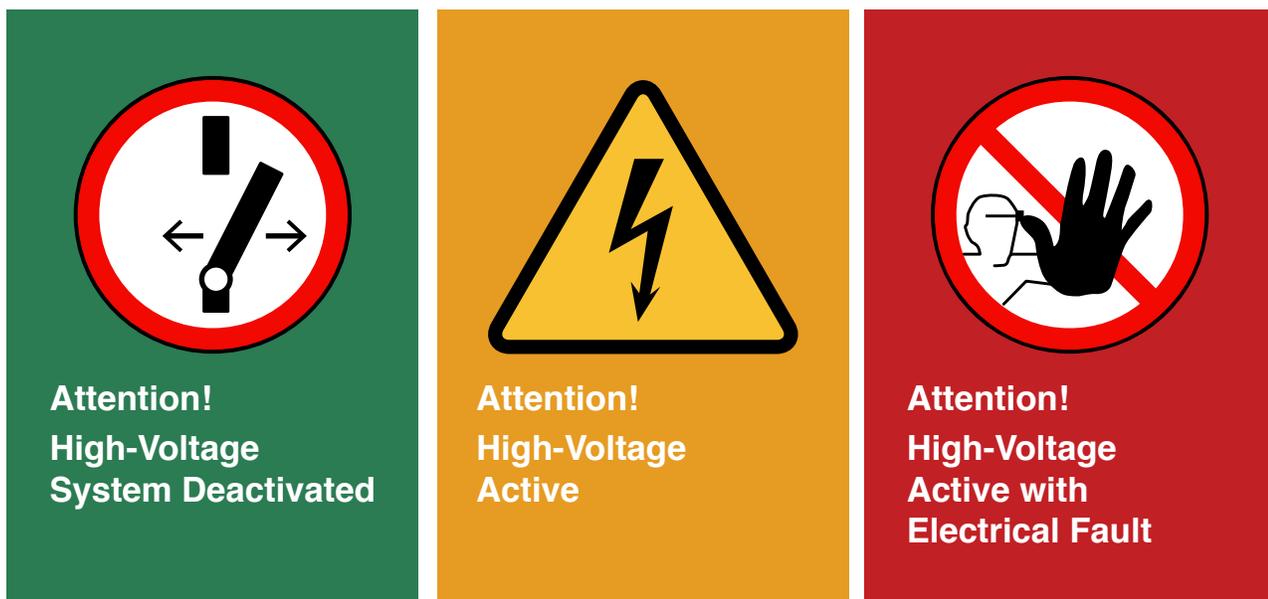
This published I-CAR Best Practice is an inter-industry developed and vetted guideline to be used in addition to the OEM procedures. This process does not take the place of any OEM procedures, OEM requirements, or contribute to any OEM specifications of skills, tooling, training, or equipment that enables a repair facility to work on high-voltage (HV) vehicles.

Only qualified high-voltage technicians with proper PPE are permitted to work on the high-voltage system. Repair facilities should always reference the documented OEM procedures for the make, model, and year of the vehicle before starting work to ensure a safe and proper repair.

This procedure is modeled after the [European regulation ECE-R-100](#) to ensure that a vehicle is safe, as there is a higher level of potential injury if there is collision damage to the HV system.

NOTE: HV will always be present inside the HV battery.

Remove dirt, debris, or liquid contaminants from any connection point before attempting to disconnect connectors.



Status Cards:

- Green: HV is deactivated
- Yellow: HV is still active
- Red: HV is active with electrical fault

NOTE: Correct PPE must be worn during all testing procedures.

HV Procedure:

1. Place safety barriers around the vehicle and affix high-voltage warning signs (yellow status card) to the vehicle.
2. Apply the parking brake or use wheel chocks to ensure the vehicle cannot be rolled.
3. Remove all charging cables HV and 12 V. No work can be performed with the charging cables connected.
4. Perform initial visual inspections.
5. Scan the entire vehicle for diagnostic trouble codes (DTCs) with focus on the HV system.
 - a. Check the battery for high temperature using a non-contact thermometer.

Connector Inspections:

- a. Inspect both mating connectors after disconnection.
- b. Inspect for evidence of physical damage or heat deformation to connector body.
- c. Inspect the latch/locking mechanisms for damage.
- d. Inspect for corrosion or terminal discoloration.
- e. Inspect for moisture or other contaminant intrusion.
- f. Verify that environmental seals are intact and undamaged.

NOTE: High voltage vehicles will have one of the following disconnect procedures. Follow the instructions for step 6 that applies to the vehicle being repaired as documented in the OEM vehicle-specific disable procedure. The procedure types are:

- Battery Disconnect
- Service Disconnect/Disconnect Loop
- Diagnostic Tool Disconnect

6. Certified disconnecting procedure – Battery Disconnect:

- a. Remove ignition keys, verify ignition is off, and store keys/fob in a locked box out of range of the vehicle. Verify the vehicle cannot be brought into READY mode. Fill out and affix the HV disconnecting label.
- b. Disconnect and insulate the negative cable of the 12 V battery. Fill out and affix the HV disconnecting label.

	Do not switch on. Person at work!	
	Place of work _____	Date _____
	Remove only by name _____	Phone _____

- c. Remove the HV battery disconnect/HV fuse and lock it in a lock box. Fill out and affix the HV disconnecting label.

6. Certified disconnecting procedure – Service Disconnect/Disconnect Loop (Low-Voltage Interrupt):

- a. Remove the ignition keys and verify the ignition is off
- b. Pull out service disconnect and install a padlock through provided hole to prevent accidental reconnection. Affix the HV disconnecting label.
- c. Store the padlock key in a lock box.
 - 1. Switch on the ignition and verify an HV disconnecting message appears on instrument cluster.
 - 2. If no message appears after service disconnect, use a diagnostic tool to verify the HV system is disconnected.
 - 3. Switch the ignition off.
 - 4. Store the keys/fob in a locked box out of range of the vehicle. Verify the vehicle cannot be brought into READY mode. Fill out and affix the HV disconnecting label.
- d. Disconnect and insulate the negative cable of the 12 V battery. Fill out and affix the HV disconnecting label.

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Place of work	Date
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6. Certified disconnecting procedure – Diagnostic Tool Disconnect:

- a. Connect an OEM-approved diagnostic tool.
- b. Scan the entire vehicle for DTCs with the focus on the HV system.
- c. Initiate the power down procedure using the scan tool.
- d. Verify the procedure successfully disconnected the HV battery from the HV system.
- e. Remove ignition keys and verify the ignition is off. Store keys/fob in a locked box out of range of the vehicle. Fill out and affix the HV disconnecting label.
- f. Disconnect and insulate the negative cable/terminal of the 12 V battery. Fill out and affix the HV disconnecting label.
- g. If the vehicle for whatever reason will not allow battery to disconnect with a scan tool, one of the other two battery disconnect procedures must be used.

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Place of work	Date
Remove only by name	Phone

7. Wait for the capacitor to discharge (drain) following the OEM recommended wait time.

8. Inspect the 2-pole tester for visible damage or defects before use (make sure it is minimum CAT 3 certified).

9. Check and verify the operation of the 2-pole tester using a known good source (for example, a 12 V DC source) before and after each measurement is made.
10. Using 2-pole voltmeter with proper PPE, check all HV component housings in the area of repair for no charge. This is done by touching one pole to the housing and the other to the chassis ground.
11. Disconnect the HV cable from the battery to the inverter to verify zero voltage. Always choose the closest location to the battery for this verification. When a factory “Y” adapter (test harness) is available, it is preferable to use it to avoid possible damage to electrical connector pins.
12. Check and verify correct function of 2-pole tester on a known source again (for example, a 12 V source) before AND after each measurement is made. This is done EVERYTIME you pick it up to use it.
13. Determine if the system is voltage free using the 2-pole volt meter:

NOTE: If no adapter is used, tests must be performed at the battery side and the inverter side of the system to test the entire HV system.

- a. Measure at the DC battery connector:
 1. Measure HV + to HV -.
 2. Measure HV + to ground (chassis).
 3. Measure HV - to ground (chassis).
- b. Measure at the connector on the cable that was removed from the HV battery going to the inverter:
 1. Measure HV + to HV -.
 2. Measure HV + to ground (chassis).
 3. Measure HV - to ground (chassis).
- c. Once again, check the 2-pole voltage tester at a known source to verify proper function.
- d. Cover any exposed HV cables and connections.
- e. If zero volts is present for all measurements, attach the green status card. This shows that it has been verified the system is disconnected and no voltage is present in the vehicle systems.

14. Enter the required measuring equipment that was used on the safety protocol sheet.

NOTE: If any voltage is still present after going through the disconnect procedure, all work must stop until a technician that is trained to work under live conditions can diagnose the problem.

Never roll an HV vehicle on the drive wheels without protecting any exposed HV wiring.

Upon disconnection of HV cables, always insert a safety block off dummy plugs or wrap the connectors with the appropriate non-conductive tape to protect connection points from contamination.

Bonding cables/straps are not removed for HV shut down and isolation. They should only be removed if required for removal of a component for access or other required service operation.

Vehicle shut down is now complete.

VEHICLE INITIALIZATION

NOTE: Bonding cables/straps should be reinstalled and bonding integrity tests (using a milliohm meter) performed before reconnecting HV and low-voltage cables.

- 1.** Verifying proper bonding (potential equalization) connection to chassis after an HV component installation/replacement.
 - a.** Use the milliohm meter (4-wire measurement method) for bonding test measurement.
 - b.** Enter the required measuring equipment (milliohm meter) that will be used on the safety protocol sheet.
 1. Legal minimum current measurement (ECE-R100) 200 mA or greater.
 2. I-CAR recommendation is a current of 1 amp (higher amps provide greater milliohm measurement accuracy).
 - c.** Check measuring equipment before use.
 1. Perform a visual inspection.
 2. Make sure it is a minimum CAT 3.
 3. Verify that the milliohm meter battery is good.
 - d.** Disconnect all communications and HV cables to the component being measured.
 - e.** Test the milliohm meter on a clean bare-metal component. Measure with probes as close to each other as possible without allowing probe tips to contact each other. The result should be close to 0 milliohm.
 - f.** Place one probe on a known good chassis grounding point, close to the HV component being tested. The other probe gets placed at three different locations on the HV component housing.
 1. Measure the HV component as close to the ground probe as possible.
 2. Measure at the middle of the HV component.
 3. Measure the HV component at the furthest distance from the ground.
 4. Enter the three milliohm meter results on the safety protocol sheet.
 5. Verify all three readings are within the expected measurement result of 1 milliohm per meter.

NOTE: If readings are not within expected measurements, bonding issues must be corrected and verified.

- 2.** Testing insulation/isolation resistance:
 - a.** Verify all communications, bonding, and HV cables for the vehicle are fully connected before measuring. All system parts and modules should be completely installed as designed by vehicle maker.
 - b.** The HV cable from the battery to the inverter must be disconnected to measure insulation resistance towards the battery and to the rest of the vehicle's HV system components.

- c. For this measurement, always choose the closest location to the battery (e.g. HV battery connection/harness) If using a “Y” connector, all tests will be performed at the “Y.”
- d. Enter the required measuring equipment (insulation meter) that will be used on the safety protocol sheet.
 - 1. Legal minimum test voltage is 1 volt above the battery’s rated voltage (ECE-R100).
 - 2. Default resistance value.
 - a. Legally ECE-R-100 (minimum insulation/isolation resistance): 500 ohms / 1 V rated voltage (example: a 100 V battery should have minimum 50,000 ohms resistance).
 - b. I-CAR recommendations should be always towards the maximum resistant value of the testing equipment or as specified by the vehicle maker.
- e. Safety rules for measuring insulation resistance:
 - 1. Wear proper PPE.
 - 2. High voltage is applied to the circuit/components while under test. Do not touch the exposed probes or connections. Warn others before starting and while performing the insulation measurement. No person should ever touch the vehicle or any high voltage component.
 - 3. Measuring time with voltage applied is approximately 5-10 seconds to allow the reading to stabilize. This ensures an accurate test result.
 - 4. Upon releasing the test button on meter/probes, keep the testing probes in place until the meter slowly reads back down to zero volts. This is showing the discharge of any capacitors in the circuit.
 - 5. Check and verify that capacitors are discharged using the 2-pole voltage tester. Check between all points tested with the insulation meter as well as between HV + and -.
- f. Perform insulation test
 - 1. Check measuring equipment before use:
 - a. Perform a visual inspection.
 - b. Make sure it is a minimum CAT 3.
 - c. Verify that the insulation test meter battery is good.

2. Perform reference measurement to verify the function of the measurement device.
 - a. Air resistance (measurement should read “open” or “infinity”).
 - b. Create a “short circuit” by touching the probes together, the measurement should read “0” ohms and volts.

Step 2a

- Record max. value and voltage built up

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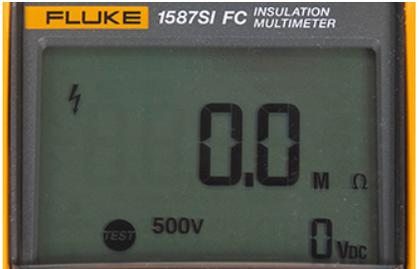
Step 2b

- Lines intact and properly connected

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NOTE: If no adapter is used, tests must be performed at the battery side and the inverter side of the system to test the entire HV system.

Correct PPE must be worn during all testing procedures.

3. Using two-pole volt meter measure at the battery side.
 - a. Perform measurement for HV+ and chassis ground.
 - b. Perform measurement for HV- and chassis ground.

4. Using two-pole volt meter measure at the inverter side.
 - a. Perform measurement for HV+ and chassis ground.
 - b. Perform measurement for HV- and chassis ground.
 - c. Perform step a and step b with probe polarity reversed to allow the AC side of the HV system to be included in the measurements (see illustration).

The measurement must be performed four times to reliably check the insulation resistance for the entire system!

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|---------------|--------------------|---------------|
| red => black | --measuring tips-- | red => black |
| 1. HV+ => GND | Change Polarity | 2. GND => HV+ |
| 3. HV- => GND | Change Polarity | 4. GND => HV- |

NOTE: If no adapter is used, tests must be performed at the battery side and the inverter side of the system to test the entire HV system.

5. Enter the measurement results into the safety protocol sheet.
 - a. If any readings are below acceptable standard, additional testing of individual components and harnesses will be required by HV specialist technician. Implement subtractive elimination of circuit parts to identify the root cause fault location.

NOTE: Correct PPE must be worn during all connecting procedures.

6. System reinitialization:
 - a. Reconnect all HV harnesses and connectors.
 - b. Reconnect in the reverse order of the specific disconnect procedure (one of the three).
 - c. Reconnect the low voltage connections (if necessary).
 - d. Reconnect the 12 V battery.
 - e. Affix the yellow status card.
 - f. Insert keys and turn on the ignition.
 - g. Make sure there are no fault codes present.
 - h. Perform a test drive.

7. Complete the safety protocol sheet and release the vehicle.

Vehicle initialization is now complete.